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TRADE-OFFS IN CHOICE BETWEEN RISK AND DELAY DEPEND ON MONETARY AMOUNTS

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In Experiments 1 and 2, 25 and 48 college students made binary choices between hypothetical money amounts. In Part A, choices were between small amounts available with certainty and larger amounts ($10 to $10,000) available with risk. Choices in Part B were between immediate small amounts and delayed larger amounts. As money amount grew, risk aversion and delay aversion both changed but in opposite ways: Risk aversion grew but delay aversion shrank. Part C of Experiment 1 pitted risky amounts against delayed amounts, and its results were consistent with those of Parts A and B. Equivalences of particular risks and delays depended on the particular monetary amounts to which they attached. In Experiment 3, 20 college students made binary choices between money amounts, knowing that they would actually receive some of the selections they made. In Part A, choices were between certain small amounts and risky larger amounts ($1 and $10). Choice problems in Part B were between immediate small amounts and delayed receipt of $1 or $10. The results were like those of Experiment 1, though weaker. These results argue against models of choice that posit an equivalence of risk and delay that is independent of monetary amount.
Key words: choice, delay, probability, income, humans

The results of several studies have led to a common conclusion that there is an equivalence between two major factors involved in making a decision: the delay to receipt of a desired outcome and the risk of not receiving it at all. It is commonly observed that increases in both the risk of not receiving a desired outcome and the delay in receiving a desired outcome diminish the value of that outcome. From that observation, and some observations of similarities in the forms of the functions relating the pattern of diminished values, it has been inferred that risk and delay function equivalently in choice.

Rotter (1954) was an early proponent of the strong view that individuals interpret delay as probabilistic (i.e., that increased delay of a reward increases the apparent risk that the reward might never arrive). Thus he suggested that probability plays the larger role in individual decision making, delay affecting people because it seems to increase risk. Mischel and Grusec (1967) studied children's choices among rewards available with and without risk and delay and also concluded that delay was effectively implicit risk. Rachlin, Logue, Gibbon, and Frankel (1986) also identified risk with delay but did not declare one to be more fundamental than the other.

Some investigators have not gone so far as to say that delay and risk represent the same process but have declared that they function equivalently in influencing choices (e.g., Navarick, 1987; Rachlin, Castrogiovanni, & Cross, 1987; Rachlin, Raineri, & Cross, 1991; Stevenson, 1986). Rachlin et al. (1991) extended the work of Rachlin et al. (1986) when they investigated the equivalence of risk and delay in choice behavior by first examining the variables individually and then in combination with each other. Their analysis of the two variables involved the establishment of a risk discount function and a delay discount function. The discount function is a measure of the reduction in utility of a good created by its riskiness or its delay. A less-than-certain chance of gaining $100 is worth less than $100, and the promise of getting $100 in a year is worth less than $100 right now.

Experiment 1 is based on a dissertation submitted by the first author to American University in partial fulfillment of the requirements for the PhD in psychology. Some of these data, together with some related research, were reported to the 1991 meeting of the American Psychological Society. This work was supported in part by a grant from the National Science Foundation to American University. Experiment 3 was supported in part by a grant from the College of Arts and Sciences of American University. We thank David Haaga, Harold Miller, Brian Yates, and several anonymous reviewers for valuable comments, critiques, and insights.

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The highest prices people would willingly pay for risky and delayed money amounts are smaller than those amounts. Those prices at various values of risk constitute the risk discount function; the delay discount function is defined analogously. Determination of the two functions and their relationships were the interests of Rachlin et al. (1991) and of the present study.

Rachlin et al.'s (1991) first experiment used two groups of people whose choices established both a probability discount function and a delay discount function. Each person in the first group was presented with several series of pairs of cards, and was to indicate a preference between a first card that presented $1,000 at a range of probabilities from 5% to 95% and a second card that presented 28 amounts of money (ranging from $1 to $1,000). In the first series of pairs, the first card always presented a 95% chance to receive $1,000, whereas the second card offered one of the several amounts of money with certainty. Participants indicated a preference in each pair. The procedure was repeated six times, replacing 95% with successive probabilities of 90%, 70%, 50%, 30%, 10%, and 5%. The responses served to locate indifference points—the equivalence of $1,000 at some probability, *p*%, and some other money amount with certainty. The amount of certain money equivalent to $1,000 with probability *p*% serves to scale the value of the risky $1,000. The equivalent certain amount declines as *p*% declines (i.e., as risk grows), and the plot of equivalent certain amounts against *p*% is the graph of the probability discount function.

In the second group, a series of delays in receipt of $1,000 replaced the probabilities in delivery of $1,000 shown to the first group. Here, the decisions involved a series of choices between $1,000 at various delays (ranging from 1 month to 50 years), and the same smaller amounts as before, immediately available. Again, the responses served to determine indifference points, equivalences of $1,000 at delay, *D,* and some other money amount immediately. Once again, the immediate money amounts can serve to scale the value of the delayed money. A plot of the equivalent immediate amounts against *D* is the graph of the delay discount function.

Both delay and risk ($1 - p$%, the likelihood of no money) devalued the $1,000 amounts to which they were attached. Indifference points changed systematically with probability or delay. The lower the probability of receiving $1,000, the lower the value of that $1,000 as measured by its certain equivalent. Likewise, the longer the delay in receiving $1,000, the lower the equivalent immediate money amount. These results are compatible with a functional equivalence of risk and delay (Rachlin et al., 1986). High risks and long delays have similar discounting effects, and it seems that for any risk there is some delay that produces the same devaluation of the $1,000. When in a second experiment a third group of participants chose between risky and certain but delayed rewards, their choices were predictable from the results of the first experiment. From these results, risk and delay can be said to be subjectively equivalent. Rachlin et al. (1991) found that a hyperbolic discounting model gave a good description of the discounting accomplished by delay and risk and of their equivalence. They remarked that there could be "interactions between amount of reward and degree of discounting" (p. 243) without specifying what form those interactions should take.

Some researchers studying choice in animals (e.g., Mazur, 1991; Mazur & Romano, 1992) have also concluded that risk and delay function equivalently and that the hyperbolic discounting model fits animal choice data too. Others, however, have concluded that risk and delay are not equivalent (e.g., Hastjarjo & Silberberg, 1992; Hastjarjo, Silberberg, & Hursh, 1990). In particular, Hastjarjo and Silberberg concluded that both the effects of risk and those of delay were dependent on overall "income" (total sessionwide reinforcement) but in opposite ways. This claim seems to be incompatible with the Rachlin et al. (1991) model.

To investigate the equivalence of risk and delay in human decisions, the present research examined their influences on choices at several monetary levels. In Experiment 1 (as in Rachlin et al., 1991), risk and delay were first studied singly (Parts A and B) and then jointly (Part C) by asking for choices between delayed and risky rewards.

EXPERIMENT 1

Pretraining

The purpose of the pretraining was to prepare participants for the experiment proper by training them in the use of the questionnaires. The questionnaires presented blocks of choices between a fixed amount of money ($240) and two orderly series of alternatives. The alternatives had a fixed dollar amount ($1,000) offered at a variety of probabilities (Series 1) or delays (Series 2). Participants were trained to indicate the point in the series at which preferences shifted from one alternative to the other.

Method

Participants. Twenty-seven students from undergraduate psychology classes at American University participated. All received course credit for participating. (Data from 2 participants were discarded for reasons discussed below, leaving 25 participants in the experiment.)

Materials. The pretraining questionnaire presented two series of choices. The first series of 19 choices, the probability practice block, asked participants to state their preference between a small dollar amount (S = $240) that was certain and a large dollar amount (L = $1,000) whose probability, p% (indicated as a percentage rather than a decimal value between 0 and 1), varied. The risky choices took the following form: ‘‘Which would you prefer: A sure gain of $$S$ or a p% chance of $$L$ today?’’ Thus, an example of a choice was ‘‘A sure gain of $240 or a 60% chance of $1,000 today?’’ Over the 19 choices, p% varied in an ascending sequence from 5% to 95% in 5% increments.

The second pretraining series, the delay series, consisted of 30 choices between S = $240 that was immediately available and L = $1,000 that came with a delay (D). The delay choices took the following form: ‘‘Which would you prefer: Receiving $$S$ today or $$L$ in D time?’’ Delay varied in an ascending sequence from 1 day to 10 years. The values of D were 1 to 6 days (in 1-day increments), 1 to 3 weeks (in 1-week increments), 1 to 11 months (in 1-month increments), and 1 to 10 years (in 1-year increments). An example of a choice in this series was ‘‘Which would you prefer: Receiving $240 today or $1,000 in 2 years?’’

The practice blocks trained participants to find what is essentially a preference threshold using a series of questions resembling a stimulus series from the method of limits. Participants were instructed to mark the alternative more preferred within each choice. When the two practice blocks had been completed, participants were informed of two patterns of preference. One pattern involved preference of one alternative for the first portion of the block, then at some point shifting to the other alternative for the balance of that block. The other pattern was to prefer one particular alternative (e.g., the riskless one) throughout the block.

These patterns were demonstrated to the participants using their own responses in the practice blocks. For each block, the series of choices with the same preference was circled. It was then explained that the purpose of the experiment was to find the point at which the shift in preference (if any) occurred.

Participants were instructed to identify their shift points as explained. The guideline was to identify preference for the first choice by circling that alternative throughout the block until the point at which preference changed to the other alternative (if preference did change). After that point, the participant was to circle the other now-preferred alternative for the remainder of the block.

Participants were then informed that they would now complete more such questionnaires, again choosing a shift point for each block of choices by circling the preferred alternatives.

PART A: VARIATION OF RISK
PART B: VARIATION OF DELAY

Method

Materials: Part A. Part A consisted of hypothetical choices among amounts of money available with various probabilities. The choices involved a small dollar amount (S) that was certain and a large dollar amount (L) whose probability (p%, as in pretraining) varied in a descending sequence. As in the probability practice block, the participant was asked, ‘‘Which would you prefer: A sure gain of $$S$ or a p% chance of $$L$ today?’’

We may think of the questionnaire as divided into four conditions, each containing nine blocks. The four conditions were named by their value of L—the $10, $100, $1,000, and $10,000 conditions. Within a condition, there were nine values of S ranging from 10% to 90% of L in 10% steps. Each value of S created a block. In the first block of the $10 condition, *S* was $9; over successive blocks of the $10 condition *S* decreased from 90% to 10% of *L* (i.e., from $9 to $1). Within each block, *p*% progressed from 90% to 10% in 10% decrements. A block was therefore a series of nine choices in which *L* and *S* were constant and *p*% varied from 90% to 10%. Steps of 10% were used for *p*% rather than the 5% steps used in pretraining to shorten the experiment. For example, then, the *L* = $10, *S* = $9 block asked, ''Which would you prefer: A sure gain of $9 or a 90% chance of $10 today? . . . A sure gain of $9 or a 10% chance of $10 today?''

A condition was a series of nine blocks in which *p*% varied within the block, *S* varied from 90% to 10% of *L* in successive blocks, but *L* remained constant. The following is an abbreviated version of the *L* = $1,000 condition:

> Which would you prefer: A sure gain of $900 or a 90% chance of $1,000 today? . . . A sure gain of $900 or a 10% chance of $1,000 today? A sure gain of $800 or a 90% chance of $1,000 today? . . . A sure gain of $800 or a 10% chance of $1,000 today? . . . A sure gain of $100 or a 90% chance of $1,000 today? . . . A sure gain of $100 or a 10% chance of $1,000 today?

Part A thus consisted of 36 blocks presented to each of 25 participants.

Procedure: Part A. Participants were tested individually in a single session consisting of pretraining and Parts A, B, and C. Session length averaged 45 min. The sequence of *L* conditions was $10, $1,000, $100, and $10,000 for all participants (as it was also in Parts B and C).

Participants indicated the shift point in each block. Responses for the first few blocks were checked to verify that the task was understood. If no errors were made, the participants were permitted to complete the questionnaire. Here, the probabilities appeared in descending order, reversing the ascending order in the pretraining block.

When a participant finished the questionnaire, the responses were checked for completeness and anomalous responses. The most common anomaly involved preferring *L* to *S* when *p*% was low, but preferring *S* to *L* when *p*% was high. For example, a participant might prefer a sure gain of $9 to a 90% chance of $10 but might also prefer a 10% chance of $10 to a sure gain of $9. Assuming that the participant would prefer a 90% chance of $10 to a 10% chance of $10, this represents an intransitivity and a violation of the monotonicity of any single probability discount function and likely reflected misunderstanding. When this confusion occurred, the participant was asked to review the first choice in the block and the choice at the shift point. This generally resulted in recognition of the confusion and a change of the relevant responses. (Two participants here or at the analogous point in Part B did not acknowledge confusion and persisted in having discount functions that were anomalous. For example, 1 participant exhibited increasing risk aversion the larger the certain alternative became, as if heightened risk increased the value of a risky outcome rather than diminishing it. This was taken to indicate a misunderstanding on the participant's part, rather than an idiosyncratic preference structure. A 2nd participant responded in Part B as if delaying a positive outcome increased its value. All of both participants' data were discarded for all three parts.)

Materials: Part B. Part B consisted of hypothetical choices between the amounts of money offered in Part A, but here delay rather than probability served to devalue the larger amount. Participants were asked to indicate their preferences between a small dollar amount (*S*) available today and a larger dollar amount (*L*) available after a delay (*D*). Participants were thus asked, ''Which would you prefer: Receiving $*S* now or $*L* in *D* time?'' As in Part A, the values of *L* ranged from $10 to $10,000, and the values of *S* ranged from 10% to 90% of *L*. The delay in receiving the larger dollar amount ranged from 1 day to 10 years, presented in ascending order. The delays used were 1 day, 2 days, . . ., 6 days, 1 week, 2 weeks, 3 weeks, 1 month, 2 months, . . ., 11 months, 1 year, 2 years, . . ., 10 years. Delays increased by one unit and the unit changed from days to weeks to months to years.

The condition and block structure of Part B paralleled that of Part A. Here a block consisted of a series of choices in which *S* and *L* were held constant and delay was varied in an ascending sequence. Thus the *L* = $100 and *S* = $90 block was, ''Which would you prefer:

Receiving $90 today or $100 after 1 day? . . . Receiving $90 today or $100 after 10 years?"

Procedure: Part B. As they had in Part A, participants in Part B responded to a 36-block questionnaire (four conditions of *L*, each with nine values of *S*). As in Part A, it usually sufficed that participants indicate where in the ascending sequence of delays in a block their preference shifted from *S* to *L*.

The most common anomaly was to prefer *S* to *L* when *D* was low but to prefer *L* to *S* when *D* was high. For example, a participant might prefer an immediate $90 to $100 in 1 day but prefer $100 in 10 years to an immediate gain of $90. Supposing that a participant would prefer $100 in 1 day to $100 in 10 years, this combination of responses indicated an intransitivity of preference. Again, when the problem was pointed out to participants, they revised their responses sensibly.

As in Part A, the sequence of *L* conditions was $10, $1,000, $100, and $10,000 for all participants.

Results and Discussion: Part A

The indifference probability (IP) was calculated for each participant in each block as the midpoint between the two values of *p*% that defined the shift point. (Recall that *S* and *L* were held constant throughout a block.) If a participant preferred *L* throughout a block, then the IP was recorded as 5%, assuming that the participant would choose *S* when *L* had a probability of zero. If a participant chose *S* throughout a block, then the IP was recorded as 95%, on the assumption that the participant would choose *L* if it too were certain.

The mean IP (averaged across participants) for each block for all conditions is shown in Figure 1. Recall that IP indexes the average chance of acquiring *L* that was equivalent in value to a sure gain of *S*. Therefore, given a choice between *L* at *p*% likelihood and *S* with certainty, a participant who behaved like the group average would choose *L* when *p*% is greater than IP (points above the IP curve) but would choose *S* when *p*% is less than IP (points below the curve). High values of IP indicate that only with a high likelihood of getting *L* would such a subject choose it over *S*. Thus, high values of IP indicate unwillingness to risk getting nothing (i.e., IP measures risk aversion).

The data of Part A exhibit two ordinal trends. First, at each value of *L* (the large risky gain), decreases in *S* (the small sure gain) reduced risk aversion. When *S* was near *L* (when *S*/*L* was near 100%), *L* was infrequently chosen, so the mean IP was large. For example, in the $100 condition, when the sure gain was $90, the average IP was .82; as *S* decreased to $10 the mean IP decreased to .27. As *S* increased, participants were more likely to choose *S* and were less willing to take a chance on a risky gain of *L*. Thus, for fixed *L*, risk aversion increased as *S* increased. This is consistent with Rachlin et al.'s (1991) results. As the plot for any value of *L* progresses down and leftward, we see that lowered values of IP occur with smaller values of *S*. The probability discount function is monotonic; the less likely the large amount, the less its prospect is worth.

The second trend is that at every value of *S*/*L* along the abscissa in Figure 1, mean IP (risk aversion) increased as *L* grew. These two trends indicate a complex dependence of the mean IP on both *S* and *L*. For instance, when *L* = $10,000 and *S*/*L* = 60%, then IP = .78. Either a change in *S*/*L* from 60% to 40% (keeping *L* = $10,000) or a change in *L* from $10,000 to $100 (keeping *S*/*L* at 60%) reduces IP to approximately .71. Thus, the average participant exhibited a systematic variation in risk aversion with condition amount, *L*. For *S* as a fixed percentage of *L*, risk aversion grew with *L*.

It is useful to consider whether individual participants' data showed the increase in mean IP (risk aversion) with increases in *L* (condition amount) at fixed *S*/*L* values. For each participant, we tested the null hypothesis that there is no effect of *L* on IP for that individual. The particular version of this hypothesis that we tested is that for every value of *L* a participant is equally likely to choose any of the nine values of IP. At each value of *S*/*L*, a participant chose four IP values, one for each *L*. Thus, there are 9^4 = 6,561 possible combinations of four IP values, and the null hypothesis declares them to be equally likely. Of the 6,561 possible combinations, 486 are monotonically increasing with *L*.[1] [By

[1] When there are *n* alternatives to choose from in each of the four conditions, there are n^4 possible combinations of four choices (in the present case, *n* = 9). Within any combination of four values, they could all be unequal,

''monotonically increasing'' we mean that IP considered as a function of L is increasing and also nondecreasing; i.e., IP(\$10,000) > IP(\$10) and also if $L_1 < L_2$ then $\mathrm{IP}(L_1) \leq \mathrm{IP}(L_2)$.] Thus, there is a probability of 486/6,561 = .074 at each S/L value that a participant's four IP values increase monotonically with L (a ''success'') and a .926 probability that they don't (a ''failure''). There are nine abscissa values, so for each participant the null hypothesis provides a binomial distribution of the number of successes in nine trials, each trial having a success probability of .074. The probability under the null hypothesis that the nine abscissa values provide zero, one, or two successes is .9756, so three successes for a participant constitute a significant departure from the null hypothesis at the $p = .025$ level. The significance level of four successes is $p = .003$, that of five successes is $p = .00022$, and p values decline further beyond that.[2]

Table 1 shows a frequency distribution of the number of instances of monotonic increase of IP with L at fixed S/L levels for the 25 participants. Of the 25 participants, 19 exceeded the chance levels from the null hypothesis at the .025 significance level or less, exhibiting more of a tendency to increase IP with L than they should. Conversely, there were almost no instances of monotonic decreases of IP with L. Two participants had one instance each (they had two and zero monotonic increases). Thus most participants followed the pattern of the group means: Increases in monetary amount produced increased risk aversion at fixed levels of S/L. This pattern is evident even though each participant provides only a single judgment at

there could be three distinct values (i.e., two of the four could be equal), there could be two distinct values (either two groups of two equal or one group of three), or all four could be equal. We consider these possibilities in turn.

When all four elements in a combination are unequal, then we can call them A, B, C, D in increasing order. They are monotonic with L when A goes with L = \$10, B goes with L = \$100, C goes with L = \$1,000, and D goes with L = \$10,000. That is the only permutation of assignments of elements to L values that is monotonic. Therefore, every combination of four distinct elements from the original n gives rise to precisely one case of monotonicity. Thus the number of possible cases of monotone increase is the same as the number of combinations of four elements that can be chosen from a set of n.

When the combination contains only three distinct values (called A, B, C in increasing order), then they are monotonically increasing with L if they are (listed in order of their L values) AABC, ABBC, or ABCC. Therefore, each choice of a group of three elements from the set of n gives three instances of monotonicity. Thus the number of possible cases of monotonic increase is three times the number of combinations of three elements that can be chosen from a set of n.

When the combination contains only two distinct values (A and B), then they are monotonically increasing with L if they are (as a function of L) AAAB, AABB, ABBB. Therefore, each choice of a group of two elements from the set of n gives three instances of monotonicity. Thus the number of cases of monotone increase is three times the number of combinations of two elements that can be chosen from a set of n.

When all four values are equal then they cannot be monotonically increasing.

Thus, the total number of monotonic increasing combinations is

$$\binom{n}{4} + 3\binom{n}{3} + 3\binom{n}{2}$$

When $n = 9$, as in Experiment 1, we have 126 + 108 + 252 = 486 combinations that are monotonically increasing with L.

[2] Bruce Schneider (personal communication, 1995) has pointed out that in regarding all possible choices of risk levels as equally likely, our null hypothesis supposes not only that participants' risk aversion levels are unconnected to monetary amounts but also that the participants are indifferent to risk altogether. A refinement might envision participants' choosing from among a group of five risk levels rather than all nine (the five highest, the five lowest, some intermediate group) and might involve a single-peaked probability distribution for those choices rather than the uniform probability that we use here.

The number of equally likely objects among which participants choose affects the likelihood that the four choices will be monotonically related to income. The larger the set from which choices are made, the smaller the likelihood of four choices being monotonic with income. In this regard, our null hypothesis is liberal and finds more significant instances of monotonicity than there would be if, for example, we imagined that choices are made equiprobably from five rather than nine risk levels. With this change from nine to five equiprobable selections, the likelihood of a set of four being monotonically increasing becomes .104 (rather than the .074 when participants choose from among nine alternatives). This change in the binomial success probability makes the chance likelihood of zero, one, or two successes .9412 (rather than the .9756 with choices from among nine alternatives). In this binomial distribution, the outcome of three successes has a significance level of .06, and four or more has a significance level of .01. With this change, the pattern of significant departures from the null hypothesis differs little from that computed on the basis of nine equiprobable alternatives. Thus this sort of change does not substantially affect our assessment of the participants' performances.

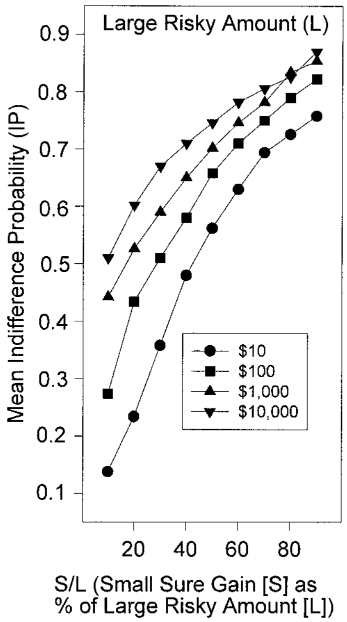

Fig. 1. Experiment 1, Part A: mean indifference probability (IP) at each value of *S/L* (in %) for all conditions.

each stimulus (*L* and *S* combination). Thus we can see the phenomenon in individual participants without repeated testing or averaging. The effect of monetary amount on risk aversion at fixed *S/L* values is quite widespread, quite reliable, and quite strong.

The growth of IP with *L* at fixed *S/L* values does not in itself demonstrate an influence of monetary amount on decision making. It would if, in addition, *S/L* were known to be the comparison between *S* and *L* that participants used to guide their decisions. Some evidence that ratios of monetary amounts do guide people's risky decisions appears in Galanter and Holman (1967). Some evidence that ratios of reinforcer magnitudes (rather than differences) guide animals' choices appears in Gibbon and Fairhurst (1994). But deciding among rival models of how participants make comparisons in general is difficult (see, e.g., Birnbaum, 1982). In this experiment, the use of the same set of *S/L* values in each condition serves merely to create a convenient well-organized set of stimuli.

Results and Discussion: Part B

The indifference delay (ID, measured in log days) was calculated for each participant in each block of the experiment. The ID was

Table 1

Experiment 1 Parts A and B: Frequency distribution of number of S/L values at which a participant's transition point (IP in Part A, ID in Part B) increased with L (condition amount).

Number of instances of monotonic increase	Number of participants: Part A	Part B
0	2	1
1	1	2
2	3	2
3	4	2
4	5	3
5	6	1
6	0	2
7	2	5
8	1	3
9	1	4

the midpoint between the highest value of *D* for which *L* was preferred and the lowest value of *D* after a shift in preference to *S*. For example, if a participant responding to the *L* = $100 and *S* = $80 block preferred $100 in a month to $80 immediately but preferred $80 immediately to $100 in 2 months, the ID was the midpoint of 1 month and 2 months. (We used 1 month = 30 days and 1 year = 12 months = 360 days for all estimations of indifference points.) If a participant preferred *L* throughout the questionnaire, the indifference point was estimated at 20 years, presuming that a 40-year delay in *L* would produce a preference for *S*. (Other choices for this estimated indifference point produced no changes in the relations among the results.)

Figure 2 shows mean ID (averaged over all participants) plotted against *S* as a percentage of *L* for all conditions. Recall that ID indexes the delayed version of *L* that was equivalent in value to an immediate gain of *S*; delays longer than the ID value induced a participant to choose *S* because the large amount would be long delayed. Thus, low values of ID indicate that participants thought that speed in acquiring *L* was required for parity with *S*; low values of ID indicate unwillingness to wait. To use a term that allows our discussion to be comparable to that in Part A, ID measures *delay aversion*. However, in this situation, low values of ID indicate great delay aversion,

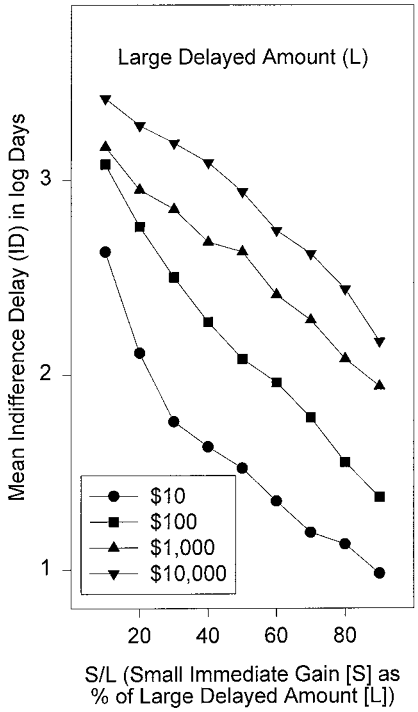

Fig. 2. Experiment 1, Part B: mean indifference delay (ID) at each value of S/L (in %) for all conditions.

whereas high values of ID indicate willingness to wait and, hence, little delay aversion.

As in Part A, choices depended jointly on S and L. For instance, when L = \$100 and S/L = 20%, ID = 2.8 log days. Either a change in S/L to 50% (keeping L = \$100) or a change in L to \$10 (keeping S/L = 20%) reduced ID to about 2.2 log days.

The plots in Figure 2 do not appear parallel. Raineri and Rachlin (1993) reported that the MANOVA used to analyze their Experiment 1 found a significant interaction of delay and amount in the determination of equivalences of small to larger delayed money amounts. Their study differed from ours in two ways. First, delay was used by Raineri and Rachlin as an independent variable, and their participants chose values analogous to what we are calling S. Second, and we hope more important, their dependent variable (S, the dollar amount equivalent in value to a value of L with a particular delay) is measured logarithmically, whereas in our study S/L is scaled arithmetically. These changes of scale can affect the degree and form of interaction found in an ANOVA. Thus we cannot easily compare the degree of interaction found in their experiment with our results. The ordinal analyses presented here do not depend on the details of the delay discounting functions at different L values (the functions that Raineri and Rachlin found to differ).

Two ordinal trends are visible in Figure 2. First, as S grew large relative to L, participants were more reluctant, on average, to wait for L. This manifests itself in the fact that ID is low toward the right side of the graph when S = 90% of L; participants were delay averse when S/L was large. For each L, as S/L decreased toward 10%, participants were more willing to choose L and, hence, were less delay averse. For example, in the \$100 condition, when S = \$90, participants would wait, on average, only about 1.4 log days (a little less than a month) for \$100. As S dropped to \$10, participants were willing to delay up to 3.1 log days (about 3.5 years) for the \$100 alternative. Thus, at every value of L, delay aversion, like risk aversion, decreased as S decreased.

The second trend involves growth in ID as a function of L for fixed values of S/L along the abscissa. Mean ID rose with L at all values of S/L. Hence, for any S/L value, the average participant exhibited progressively less delay aversion as L increased from \$10 to \$10,000.

As in Part A, it is useful to consider whether individual participants' data exhibited the increase in ID (decrease in delay aversion) with L (condition amount) at all S/L values. Once again, we inspect individual participants for conformity to the null hypothesis that L exerts no influence on ID by counting the number of values of S/L (out of nine) at which a participant's ID values increased monotonically with L. Here, participants chose from a list of 30 possible ID values, so the number of possible combinations of ID values is 30^4 = 810,000; of these, 40,890 are cases of monotonic increase. This creates a binomial distribution with a success probability of .05048 and nine trials. In this distribution, three successes constitute a significant departure from the null hypothesis in the direction of agreement with the group data with a .01 significance level, four successes have a significance level of p = .001, and significance levels decline further beyond that. Of the 25 participants, 20 have three or more instances. Two of those 20 were the only participants with any instances of monotone decreases, and they had only one each. Table 1 shows the frequency distribution of the number of participants having various numbers of increases of ID with L. Here, as in Part A, the group means exhibit the pattern that most individual participants followed. This time the pattern is that at fixed values of S/L, increases in monetary amount diminish delay aversion. Also as in Part A, this conclusion is based on each participant's providing only a single judgment for each stimulus. Here too, the effect of monetary amount on delay aversion is widespread, reliable, and strong.

The combination of Parts A and B shows that for fixed values of S/L, both risk aversion and delay aversion vary with monetary amount. However, they vary in opposite directions. Increases in L served to increase risk aversion but to reduce delay aversion. This finding recalls the conclusion of Hastjarjo and Silberberg (1992) that both the effects of risk and those of delay were dependent on overall income (in their case, total session-wide reinforcement received by pigeons) but in opposite ways.

The fact that all participants encountered the four L conditions in the same sequence in both Parts A and B makes it possible that the stimulus sequence contributed in some way to the results. We address this possibility in Experiment 2, below. Nonetheless, with the particular sequence of stimuli in Experiment 1, for any fixed level of S/L, as L grows from \$10 to \$10,000, risk aversion grows and delay aversion shrinks.

Part C: Variation of Risk and Delay

Method

Participants. The 25 participants whose data are reported in Parts A and B participated in Part C as well.

Materials. The questionnaire consisted of choices between amounts of money that were probabilistic and others that were delayed. For example, "Which would you prefer: A $p\%$ chance of \$10 today or \$10 in D time?" The money amounts were again L = \$10, \$100, \$1,000 and \$10,000, and defined conditions. Blocks, however, were here defined by probabilities, $p\%$, which, as they had in Part A, ranged from 10% to 90%. Delays, D, were those from Part B.

In this experiment a block was a series of choices in which L and $p\%$ were constant and D increased from 1 day to 10 years. A condition was a series of nine such blocks that involved successively smaller values of $p\%$, $p\%$ decreasing from 90% to 10%. In the L = \$10 condition, the initial block offered a $p\% = 90$ chance of \$10 today or \$10 in D; in successive entries within that block D increased from 1 day to 10 years, as in Part B. For example, the L = \$10, $p\% = 90\%$ block was "Which would you prefer: A 90% chance of \$10 today or \$10 in 1 day? . . . A 90% chance of \$10 today or \$10 in 8 months? . . . A 90% chance of \$10 today or \$10 in 10 years?" The L = \$10 condition was a series of nine such blocks, with successive blocks having $p\% = 90\%, 80\%, \ldots, 10\%$.

Procedure. As they had in Parts A and B, the 25 participants in Part C responded to a 36-block questionnaire (four conditions: L = \$10, \$100, \$1,000, and \$10,000, each with nine values of $p\%$). As in Parts A and B, it usually sufficed that participants indicated where in the ascending sequence of delays in each block their preference shifted from the delayed to the risky alternative.

When participants completed the questionnaire, their responses were reviewed for anomalies. As in Parts A and B, participants came to appreciate what few misunderstandings they had and adjusted their choices accordingly.

As in Parts A and B, the sequence of L conditions was \$10, \$1,000, \$100, and \$10,000 for all participants.

Results and Discussion

The average indifference delay (in log days) was calculated for each block, as in Part B. Here it will be referred to as the probability indifference delay (PID) because it was the indifference delay for a particular value of $p\%$. Figure 3 shows the mean PID values averaged across participants at each value of $p\%$ in each condition (L). In this graph, as in Figure 2, high values of PID represent high willingness to wait for the delayed alternative, so low values of PID indicate high delay aversion. But in Part C the delayed alternative is the certain alternative, whereas the immediate one is risky. Hence, we may also interpret

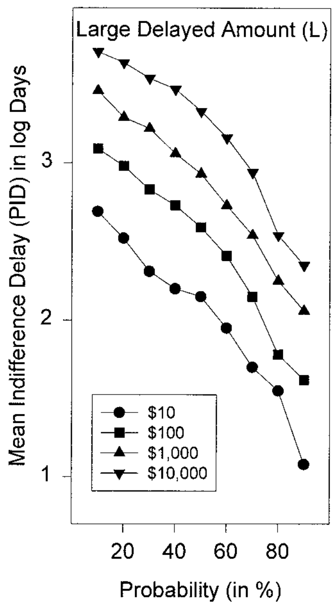

Fig. 3. Experiment 1, Part C: mean probability indifference delay (PID) at each value of *p*% for all conditions.

Table 2

Experiment 1 Part C: Frequency distribution of number of P% values at which a participant's PID values increased with condition amounts.

Number of instances of monotonic increase of PID	Number of participants
0	1
1	2
2	1
3	3
4	1
5	2
6	3
7	4
8	7
9	1

PID as representing a measure of risk aversion for which high values of PID indicate high risk aversion. Thus, this graph pits delay aversion against risk aversion in that as PID increases, risk aversion increases and delay aversion decreases. Of course, this means that increases in PID are ambiguous in that they may indicate increased risk aversion, reduced delay aversion, or both.

In every condition, the mean PID decreased as *p*% increased. Increases in *p*% are decreases in the risk of getting nothing, so these results show that risk aversion shrank (or delay aversion grew) as risk diminished. Mean PID depended on both *p*% and *L*. For instance, mean PID for $L = \$1,000$ at $p\% = 40\%$ is about 3.1 log days. Either increasing *p*% to 80% for $L = \$1,000$ or reducing *L* to \$10 at $p\% = 30\%$ reduced mean PID to about 2.25 log days.

Most important is the dependency of mean PID on *L*, the condition amount. At all values of *p*%, mean PID increased as *L* increased. Therefore, as *L* increased, risk aversion grew, delay aversion shrank, or both. This recalls the pattern of results found in Parts A and B in which, at any *S/L* value, as *L* increased from \$10 to \$10,000, risk aversion grew (Part A) and delay aversion shrank (Part B). But in this experiment, the plot for any value of *L* indicates the trade-off between risk and delay. The plot for a single value of *L* shows which values of risk and delay are, on average, equivalent at that value of *L*. What the data in Figure 3 show is that the equivalences between risks and delays changed systematically as *L* changed in accord with the patterns found separately in Parts A and B.

As in Parts A and B, it is useful to consider whether individual participants' data exhibited the increase in PID (increase in risk aversion or decrease in delay aversion) with *L* (condition amount). Once again, we inspect individual participants' data for conformity to the null hypothesis that *L* exerts no influence on PID by counting the number of values of *p*% (out of nine) at which a participant's ID values increased monotonically with *L*. Here, as in Part B, participants chose from a list of 30 possible ID values, so the binomial distribution again has nine trials, and success probability was .05048. Again, three successes constitute a significant departure from the null hypothesis in the direction of agreement with the group data with a .01 significance level, four successes have a significance level of $p = .001$, and significance levels decline further beyond that. Of the 25 participants, 21 had three or more such instances. One of the other four was the only participant with any instance of monotone decrease; that participant had one monotone increase and one monotone decrease. Table 2 shows the frequency distribution of the number of participants having various numbers of increases of ID with L.

Here, as in Parts A and B, the group means exhibit the pattern that most individual participants followed. This time the pattern is that increases in monetary amount diminish delay aversion (as was true at each S/L level in Part B) or increase risk aversion (as was true at each S/L level in Part A). Also as in Parts A and B, this conclusion is based on each participant's providing a single judgment for each stimulus. Even in this somewhat more complicated judgment setting, the effect of monetary amount on risk aversion and delay aversion is widespread, reliable, and strong.

Rachlin et al. (1991; following Mazur, 1987) found that their data were consonant with a model in which the discounting due to both delay and risk followed a hyperbolic function rule. The important variables in their model were delay (rather than its logarithm) and a quantity they call "odds against" (rather than risk). Odds against (hereafter, OA) is $(1 - p\%)/p\%$, where $p\%$ is the probability of getting a risky reward. So, for example, a reward whose likelihood is $p\% = 20\%$ has a corresponding OA of $80\%/20\% = 4$. The hyperbolic model predicts a proportional relation between delay and OA within any condition level of L (Rachlin et al., 1991, p. 240, Equation 9). The model predicts that the relation of log(PID) to log OA should be a straight line with a slope of 1. Rachlin et al.'s data came from an experiment in which L = \$1,000. The best fitting straight line had $r^2 = .96$ and a slope of 0.988, a value impressively close to 1.

In the analogous analysis of our data, as L grew from \$10 to \$10,000, the values of r^2 were .97, .95, .97, and .92 (similar in magnitude to Rachlin et al.'s, 1991, value) but the slopes were 0.83, 0.84, 0.79, and 0.78. These slopes are quite close to each other and to 0.8; the fact that r^2 is uniformly high suggests that they are not just reliable bad sample approximations to true slope values of 1. Thus, our results do not conform to one prediction of the hyperbolic discounting model that so well fit the data of Rachlin et al. (1991).

The intercepts for the four regression analyses were 4.6, 5.7, 6.5, and 7.3 as L grew from \$10 to \$10,000. These intercept values indicate the relative degrees of discounting for risk and delay; their increase with L indicates that as L grows, risk aversion grows relative to delay aversion, as we saw in Figure 3.

There is a pair of modifications to the hyperbolic discounting model that would permit it to accommodate both the present results and those of Rachlin et al. (1991). First, the degree-of-discounting parameters (h and k in Equation 9, p. 240, of Rachlin et al.) can be made dependent on monetary amount. Second, discounting could depend on power function transformations of delay or OA or both rather than on delay and OA per se. We have not investigated the wisdom or the consequences of these modifications. We point them out to make clear that our results are not in conflict with the general notion of hyperbolic discounting but only with the particular simple version of the process that served as a successful model for the data of Rachlin et al.

Discussion: Parts A, B, and C

Part C provides confirmation that, as Parts A and B indicated, risk and delay both devalued the money amounts to which they attached, but separately. Their interactions with the size of money amount were quite different. These results are not compatible with the idea that delay is merely implicit risk.

There are important limitations on the generality of conclusions that one can draw from these results. Throughout Experiment 1, sequence of presentation of stimuli was the same for all participants. For example, all participants encountered the L conditions in the same sequence: \$10, \$1,000, \$100, \$10,000. The sequence was not monotonically increasing or decreasing, but it was the same for all participants. Experiment 2 investigates whether Experiment 1's results depend on that fact.

EXPERIMENT 2

To determine whether sequence of L conditions was the source of the effect of L on risk aversion and delay aversion, we performed a reduced version of Experiment 1 in which the sequence of L conditions varied.

Method

Participants. Forty-eight students from undergraduate psychology classes at American

University participated. They received no rewards for their participation.

Materials. Questionnaires like those in Experiment 1 but including only S/L values of 30% and 70% were used. All 24 (4!) possible sequences of the four L conditions were used twice. Twenty-four participants responded to the risk questions before the delay questions (Part A before Part B), and the other 24 had the delay questions first (the sequence of L conditions was the same for risk and delay questions.) Within an L condition, half the questionnaires had S/L = 30% questions before S/L = 70% questions; this variation was crossed with the others.

Thus each participant saw a unique sequence of questions. Questions in the L = \$100 condition pitted a sure (or immediate) \$30 (or \$70) against a variably risky (or delayed) \$100. The L = \$10, \$1,000, and \$10,000 questions were constructed analogously.

Procedure. After training as in Experiment 1, participants indicated the shift point in each block of questions. All participants completed the task with no obvious confusion.

Results: Part A

As in Experiment 1, Part A, we computed the IP for each participant in each S/L block. These participants' mean IP values grew with L, as had those in Experiment 1, Part A. The mean IP values at S/L = 30% were .36, .53, .62, and .66 (vs. values of .36, .51, .59, and .67 for participants in Experiment 1, Part A) for the L conditions \$10, \$100, \$1,000, and \$10,000, respectively. The mean IP values at S/L = 70% were .63, .73, .76, and .80 (vs. values of .69, .75, .78, and .81 for participants in Experiment 1, Part A) for the L conditions in ascending order.

As in Experiment 1, we use the binomial distribution with p = .074 to evaluate individual performances against the null hypothesis that at each value of L people are equally likely to choose any of the nine possible IP values. The probabilities of seeing zero, one, or two instances of monotonicity for any individual are .8575, .1370, and .0055. Of the 48 participants, 15 had two instances of monotonicity, 19 had one, and 14 had none. (Five participants had one instance of IP values decreasing monotonically as L increased; none had two such instances.) If we restrict our interest to the extreme values of L, 38 of the 48 participants had greater IP values for L = \$10,000 than for L = \$10 when S/L = 30%, and 31 of the 48 did so when S/L = 70% (vs. 1 and 6 participants at those two S/L values whose IP values were greater for L = \$10 than for L = \$10,000).

Thus the individual participants' data tended to exhibit the pattern shown by the average IP values: IP grew with L. Of course, a statistical test with only two S/L values has considerably less power than does the test with nine values in Experiment 1. Here only about a third of the participants departed significantly from the null hypothesis with $p <$ .05. Still, most departed from the hypothesis in the same direction as did those in Experiment 1, and very few went the other way (none of those significantly).

Results: Part B

As in Experiment 1, Part B, we computed the ID (again in log days) for each participant in each S/L block. These participants' mean ID values grew with L, as had those in Experiment 1, Part B. The mean ID values (in log days) at S/L = 30% were 1.86, 2.50, 2.86, and 3.05 (vs. values of 1.76, 2.50, 2.85, and 3.19 for participants in Experiment 1, Part B); the mean ID values at S/L = 70% were 1.33, 1.95, 2.38, and 2.60 (vs. values of 1.19, 1.78, 2.28, and 2.62 for participants in Experiment 1, Part B).

As in Experiment 1, Part B, we use the binomial distribution with p = .0505 to evaluate individual performances against the null hypothesis that at each value of L people are equally likely to choose any of the 30 possible ID values. The probabilities of seeing zero, one, or two instances of monotonicity for any individual are .9026, .0959, and .0026. Of the 48 participants, 28 had two instances of monotonicity, 11 had one, and 9 had none. (One participant's ID values decreased monotonically as L increased both when S/L = 30% and when S/L = 70%; no other monotone decreases occurred.) If we restrict our interest to the extreme values of L, 41 of the 48 participants had greater ID values for L = \$10,000 than for L = \$10 when S/L = 30%, and 43 of the 48 did so when S/L = 70% (vs. 3 and 3 participants at those two S/L values whose ID values were greater for L = \$10 than for L = \$10,000).

Thus the individual participants' data tended to exhibit the pattern shown by the average ID values: ID grew with *L*. The pattern is clearer here than it was in Experiment 2, Part A; 58% of the participants departed significantly from the null hypothesis in the direction of the means even with the reduced power of the statistical test.

Discussion

Sequence of *L* conditions had little impact on the participants' responses. Participants with varied and balanced *L* condition sequences still responded as had those with only a single sequence of *L* conditions in Parts A and B. Thus although some numerical details of the results of Experiment 1 (Parts A and B) may be dependent on the *L* condition sequence, the general picture is not. For most participants, for any fixed level of *S/L*, as *L* grew from $10 to $10,000, risk aversion grew and delay aversion shrank.

There were, however, other invariant sequential properties in our procedure. For example, all choices in Parts A, B, and C presented the small *S* before the delayed or risky *L* (e.g., "A sure gain of $100 or a 90% chance of $1,000 today"). Furthermore, in Part A, *p*% preceded *L* but in Part B, *L* preceded the delay (e.g., "$1,000 after 3 months"). Throughout Experiments 1 and 2 all questionnaire pages had a list of choices in which high risks and short delays appeared at the top of the list and low risks and long delays appeared at the bottom. Would the results change if any of these were changed, reversed, or randomized? We have not investigated this question experimentally.

An additional procedural question arises from the fact that in Experiment 1, Part C, subjects chose delays to match risks. Would people choosing risks to match delays produce the same trade-off functions? We did not investigate that question experimentally.

With the procedures we did use, the results of Experiment 1 and 2 come from choices among hypothetical outcomes. Will the results be similar if people choose among real monetary outcomes? It is to this issue that we address Experiment 3.

EXPERIMENT 3

Experiments 1 and 2 show that participants exhibit an income-dependent nonequivalence of risk and delay when responding to questions about what selections they *would* make when faced with particular choices. Will we find those same nonequivalences when participants make choices between real alternative outcomes? Experiment 3 replicated some of the essential structure of Experiments 1 and 2 with the added feature that participants knew that they were liable to receive what they chose.

Experiment 3 consisted of pretraining (which familiarized the participants with the style of questionnaire used in the experiment proper) and Parts A and B.

Pretraining

As was the case in Experiments 1 and 2, pretraining served to prepare participants for the experiment proper by training them in the use of the questionnaires. The pretraining questionnaires presented series of choices between a small amount of certain immediate money (S = $2) and two orderly series of alternatives. The alternatives had a large dollar amount (L = $5) offered at a variety of probabilities or at a variety of delays.

Method

Participants. Twenty students from undergraduate psychology classes at American University participated. They received monetary rewards that were dependent on their selections and on the outcomes of chancy events. The maximum possible monetary reward was $22.

Materials. The two-page pretraining questionnaire presented two series of choices. One page was a series of 19 choices, the probability practice series, that asked participants to indicate their preference between a small dollar amount (S = $2) that was certain and a large dollar amount (L = $5) whose probability, *p*% (indicated as a percentage rather than a decimal value between 0 and 1), varied. Over the 19 choices, *p*% varied in an ascending sequence from 5% to 95% in 5% increments. This page of the questionnaire, then, asked, "Which would you prefer: A sure gain of $2 or a 5% chance of $5 today? . . . A sure gain of $2 or a 95% chance of $5 today?"

The other page of the pretraining questionnaire was the delay practice series, choices between S = $2 that was immediately available and L = $5 that came with a delay,

D. Over the 22 choices, D rose from 1 day to 2 years. The values of D were 1 to 6 days (in 1-day increments), 1 to 3 weeks (in 1-week increments), 1 to 11 months (in 1-month increments), 1 year, and 2 years. This page of the questionnaire, then, asked, ''Which would you prefer: Receiving \$2 today or \$5 in 1 day? . . . Receiving \$2 today or \$5 in 2 years?''

Procedure. Probability preceded delay pretraining questions for the 10 participants who would encounter probability questions before delay questions in Parts A and B. The pretraining questions served to teach participants to mark each line so as to indicate which alternative, the left or right one, they preferred. When the two practice pages had been completed, participants were shown their patterns of preference, preference for one alternative for the first several questions and then at some point a shift to the other alternative for the remaining questions. Participants were then informed that they would now respond to more such questions, again choosing one of two alternatives in each. Further, they were informed that after they were done they would participate in the random selection of some of those questions and that they would in fact receive the things they had said they preferred in those randomly selected questions.

Part A: Variation of Risk
Part B: Variation of Delay

Method

Materials: Part A. Part A consisted of hypothetical choices among amounts of money available with various probabilities. The choices involved a small dollar amount (S) that was certain and a large dollar amount (L) whose probability (p%, as in pretraining) varied in an ascending sequence. As in the probability practice questions, the participant was asked, ''Which would you prefer: A sure gain of \$$S$ or a p% chance of \$$L$ today?'' We may think of the questionnaire as divided into two conditions, each containing two blocks. The two conditions were named by their value of L: the \$1 and \$10 conditions. Within a condition, there were two values of S: 30% of L and 70% of L (\$0.30 and \$0.70 when L = \$1; \$3 and \$7 when L = \$10). The four combinations of L and S are the four blocks. p% progressed from 10% to 90% in 10% increments within each block. Blocks appeared on separate pages of the questionnaire. For example, the L = \$10, S = \$3 block asked, ''Which would you prefer: A sure gain of \$3 or a 10% chance of \$10 today? . . . A sure gain of \$3 or a 90% chance of \$10 today?''

Materials: Part B. Part B consisted of hypothetical choices between the amounts of money offered in Part A, but here delay rather than probability served to devalue the larger amount. Participants were asked to indicate their preferences between a small dollar amount (S) available today and a larger dollar amount (L) available after a delay (D). As in the delay practice questions, participants were asked, ''Which would you prefer: Receiving \$$S$ now or \$$L$ in D time?'' As in Part A, the values of L were \$1 and \$10, and the values of S were 30% and 70% of L. The delays in receiving the larger dollar amount ranged from 1 day to 2 years, presented in ascending order. The delays listed were 1 day, 2 days, . . ., 6 days, 1 week, 2 weeks, 3 weeks, 1 month, 2 months, . . ., 11 months, 1 year, 2 years. Delays increased by one unit, and the unit changed from days to weeks to months to years.

The condition and block structure of Part B paralleled that of Part A. Here a block consisted of a series of choices in which S and L were held constant and delay varied in an ascending sequence. For example, the L = \$10 and S = \$3 block was, ''Which would you prefer: Receiving \$3 today or \$10 after 1 day? . . . Receiving \$3 today or \$10 after 2 years?''

Procedure. Each participant received an eight-page questionnaire. For half the participants, pages 1 to 4 had variations of p% (the likelihood of receiving L, the larger amount) and pages 5 to 8 had variations of D (the delay to receipt of L); for the other half this sequence was reversed. For half the participants, the \$1 questions preceded the \$10 questions. For half the participants, S = 30% of L questions preceded S = 70% of L questions. All three of these constraints were crossed over participants.

Having completed the questionnaire, the participant rolled dice and chose cards with numerals on them so as to specify one choice from each of the \$1 and \$10 conditions in each of the probability and delay series. Participants were given whatever they had selected in those four choices: immediate cash, chances to win immediate cash, or receipts for cash they could claim in the future.

Results and Discussion: Part A

As in Experiments 1 and 2, Part A, each participant's IP was calculated as the midpoint of the highest probability at which the participant preferred S with certainty and the lowest probability at which the participant would gamble on winning L. Here, as in Experiments 1 and 2, increases in IP indicate increase in risk aversion.

As happened in Experiments 1 and 2, Part A, mean IP grew as L increased from \$1 to \$10 at both values of S/L. When S/L was 30%, mean IP grew from .40 to .51 (vs. .36 at \$10 in both Experiments 1 and 2); when S/L was 70%, mean IP grew from .60 to .75 (vs. .69 and .63 at \$10 in Experiments 1 and 2). Thus, the pattern of responses matched that in Experiments 1 and 2, Part A: At each value of S/L, risk aversion grew with L. The IP values for $L = \$10$ are quite similar for Experiments 1, 2, and 3 when $S/L = 70\%$ but were not so similar when $S/L = 30\%$. When $S/L = 30\%$, mean risk aversion was greater with a real \$10 than with a hypothetical \$10.

Because we have only two L values, we cannot test statistical significance within participants as we did in Experiments 1 and 2. Here we analyze the data with sign tests, testing the null hypothesis that as L grows from \$1 to \$10, randomly chosen individual participants are equally likely to exhibit increases and decreases in risk aversion. Essentially our criterion for significance is across-participant reliability in a binary comparison. By this standard, the increase in risk aversion from $L = \$1$ to $L = \$10$ was not reliable enough to achieve statistical significance when S/L was 30%. Of the 20 participants, 8 exhibited no change in IP as L went from \$1 to \$10. Of the remaining 12 participants, 8 exhibited a growth in risk aversion with L and 4 exhibited a decrease. A conservative approach to the sign test is to divide the 8 participants who didn't change into four pseudoincreases and four pseudodecreases (as in Neave & Worthington, 1988). Doing so, we get 12 of 20 participants whose risk aversion grew with L ($p > .50$, two-tailed).

The increase in risk aversion with L was significant when S/L was 70%, however. Of the 20 participants, 7 exhibited no change in IP as L went from \$1 to \$10. Of the remaining 13 participants, 12 exhibited growth in risk aversion with L. Dividing the seven unchanged cases into three pseudoincreases and four pseudodecreases, we get 15 of 20 participants whose risk aversion grew with L ($.04 < p < .05$, two-tailed).

Thus the patterns found extensively in Experiments 1 and 2 (Part A) with large amounts of hypothetical money also appear in Experiment 3 (Part A) with small amounts of real money. For fixed values of S/L, risk aversion grew with L. Most participants were more risk averse at $L = \$10$ than at $L = \$1$, that majority being significant when $S/L = 70\%$. Few participants indicated less risk aversion at $L = \$10$ than at $L = \$1$.

Results and Discussion: Part B

As in Experiments 1 and 2, Part B, each participant's indifference delay (ID) was calculated as the midpoint (in log days) between the highest value of D for which L was preferred and the lowest value of D after a shift in preference to S.

As happened in Experiments 1 and 2, Part B, mean ID grew as L increased from \$1 to \$10 at both values of S/L. When S/L was 30%, mean ID grew from 18.9 to 26.9 days (vs. 57.5 and 72.4 days for $L = \$10$ in Experiments 1 and 2, Part B); when S/L was 70%, mean ID grew from 6.4 to 11.6 days (vs. 15.5 and 21.4 days for $L = \$10$ in Experiments 1 and 2, Part B). Recall that increases in ID are reductions in delay aversion. The pattern of responses matched that in Experiments 1 and 2, Part B: At each value of S/L, delay aversion shrank as L grew. The ID values are smaller in Experiment 3 (Part B) than they were in Experiments 1 and 2 (Part B), indicating more unwillingness to wait for a real \$10 than for a hypothetical \$10.

The decrease in delay aversion was almost reliable enough to achieve statistical significance when S/L was 30%. Again analyzing the data with sign tests, of the 20 participants, 8 exhibited no change in ID as L went from \$1 to \$10. Of the remaining 12 participants, 10 exhibited a growth in ID with L. Dividing the 8 participants who didn't change into four pseudoincreases and four pseudodecreases, we get 14 of 20 participants whose ID grew with L ($.11 < p < .12$, two-tailed).

The reduction in delay aversion as L grew was similarly almost significant when S/L was 70%. Of the 20 participants, 3 exhibited no change in ID as L went from \$1 to \$10. Of the remaining 17 participants, 13 exhibited growth in ID with L. dividing the three unchanged cases into one pseudoincrease and two pseudodecreases, we get 14 of 20 participants whose delay aversion grew with L ($.11 < p < .12$, two-tailed).

Thus, the patterns found extensively in Experiments 1 and 2 (Part B) with large amounts of hypothetical money also appear in Experiment 3 (Part B) with small amounts of real money. For fixed values of S/L, delay aversion shrank as L grew. Participants tended to be more delay averse at L = \$1 than at L = \$10 with a significance level of about .12. Only 4 participants indicated less delay aversion at L = \$1 than L = \$10.

Discussion: Parts A and B

The pattern of results found in Experiments 1 and 2 on hypothetical money was generally recreated in Experiment 3 on small amounts of real money. At both values of S/L (30% and 70%) as L grew, risk aversion grew and delay aversion shrank. The effects were not so clear-cut with small amounts of real money and small numbers of participants as they were with larger amounts of hypothetical money and larger numbers of participants. But the direction of the effects replicated that in Experiments 1 and 2, even if the magnitude was smaller.

GENERAL DISCUSSION

The experiments reported here were designed to address models (e.g., Rachlin et al., 1991; Stevenson, 1986) that propose that risk and delay are equivalent in their effects on choice behavior. We found, contrary to such models, that risk and delay were not equivalent. It is true that within any level of L, there is some delayed version of L that is equivalent to some risky version of L. But what particular values of delay and risk are equivalent depends on the value of L. Thus there is no general formula that can describe the equivalences of delays and risks without explicitly including the monetary amount. As monetary amount rises, risk becomes progressively a more powerful and delay a less powerful force in discounting.[3] A model that views choice as dependent on terms identified with risk and delay must make at least one of those terms functionally dependent on monetary amount if it is to account for these results.

It would be interesting to extend the present studies to preferences in the context of the threat of losses rather than gains. People make decisions about losses differently from how they make decisions about gains (e.g., Kahneman & Tversky, 1984), so relationships among risks, delays, and monetary losses might be different from the relationships involving gains reported here. Mischel and Grusec (1967) found that children paid little attention to delays (ranging from 1 day to 1 month) in choosing among unpleasant prospects (these being events such as eating bad-tasting foods rather than monetary losses). Stevenson (1986) found that a single model handled choices among losses and choices among gains.

The present results have an important implication for models of choice. They show that any model of choices among positive outcomes that posits that delay and risk are

[3] The procedures of Parts A, B, and C were conducted on an additional group of 20 participants using just one L condition, L = \$10 billion (otherwise, all procedural details were as described previously). We will call these Parts A2, B2, and C2. The performances in Part A2 (risk) exhibited almost total risk aversion, extending the pattern in Part A in which risk aversion increased with L. Values of mean IP (refer to Figure 1) exceeded .9 at all levels of S/L. Performances in Part B2 did not extend the pattern of Part B, however. These participants' delay aversions (mean ID in Figure 2) were almost indistinguishable from the values for L = \$1,000 in Part B; ID values were distinctly below those for L = \$10,000 but above those for both L = \$10 and L = \$100 at all S/L levels. Mean PID values (see Figure 3) in Part C2 were higher than those for any of the conditions of Part C, exceeding 3.5 log days at all S/L levels.

If we combine these results with those of the participants who served in the four conditions of Parts A, B, and C, we find that risk aversion continues to grow as monetary amount grows but that delay aversion is bitonically related to monetary amount. On average, participants will wait an extra year to get \$10,000 rather than \$8,000 now; they will wait only about 3 months to get \$10 billion rather than \$8 billion now. As the amount of money grows beyond some large value, the tendency to ''take the money and run'' increases. Unfortunately, these were different participants from those in Parts A, B, and C, and amalgamation of the two data sets may not be altogether appropriate.

equivalent (e.g., that delay is implicit risk) must make risk-delay equivalences dependent on outcome magnitude.

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